Title of the Invention:

ELECTROMAGNETIC DRIVE DEVICE

INCORPORATION BY REFERENCE

This application is based on and claims priority under 35 U.S.C. sctn. 119 with respect to Japanese Application No. 2003-044940 filed on February 21, 2003, the entire content of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention relates to an electromagnetic drive device for linearly reciprocatively moving an operating member such as, for example, a spool of a spool valve.

Discussion of the Related Art:

Heretofore, as electromagnetic drive device for reciprocatively moving a spool of a spool valve, there has been known one described in Japanese unexamined, published patent application No. 1-242884 (1989-242884). In the known electromagnetic drive device, a first solenoid housing (i.e., core) and a second solenoid housing (i.e., yoke) both made of a magnetic material are arranged serially in axial alignment with a non-magnetic portion (i.e., air gap or non-magnetic member) placed therebetween, thereby to constitute a stator, and a plunger is slidably guided in an inner bore formed in the stator. By exciting the solenoid housings with a solenoid, the plunger is axially moved against a spring, so that a spool in a spool or valve housing attached to the first solenoid housing (i.e., core) is operated. Where the plunger is slidably received in the inner bore of the stator in this manner, a strict alignment is required between the internal surfaces of the yoke and the core. Therefore, it is necessary to machine the

internal surfaces of the yoke and the core after they are inserted into and secured to a sleeve made of a non-magnetic material.

Further, there has also been known a technology described in United States patent No. 6,601,822 B2 to S. Tachibana et al. In this known technology, a stator for slidably guiding a plunger is constituted as a cylindrical stationary core which is made as one piece of a magnetic material, and a thin annular portion is formed by partly cutting out the outer wall portion at the axial mid position of the stationary core radially facing the plunger to the extent that the mechanical strength thereat is not deteriorated. A plurality of radial through holes are formed in the thin annular portion to decrease the area for magnetic path and thereby to increase the magnetic resistance thereat so that a portion equivalent to a non-magnetic portion can be formed at the thin annular portion.

Further, there is known a technology described in a technical journal "Materia Japan", vol. 36, No. 4 (1997), pages 358-360. In this technology, a non-magnetic pipe made of a quasi-austenite base stainless steel is first converted by a cold roll process into a magnetic pipe, which is then partly processed by a selective quenching, whereby a magnetic stator with a non-magnetic portion at its axial mid portion can be made.

However, in the technology described in the aforementioned Japanese application, problems are raised in that the number of parts constituting the electromagnetic drive device increases and that many steps are needed for the machining of the fitting portions, press-fittings, and the finish machining of the inner bore for the plunger after the press-fittings, thereby resulting in an increase of the manufacturing cost. On the other hand, the problem of an increase in the manufacturing cost can be solved in the technology described in the aforementioned United States patent. That is, in the second technology, the annular portion is made thin and is provided with the plural radial through holes thereby to increase the magnetic resistance thereat. However, since it is unavoidable that the magnetic flux leaks through the annular portion, there is raised another problem that the magnetic attraction force exerted on the plunger is weakened. Further, the last mentioned technology for partly

processing the magnetically converted stainless steel pipe by a selective quenching process needs plural steps of special processing, which undesirably results in an increase in the manufacturing cost.

SUMMARY OF THE INVENTION

Accordingly, it is a primary object of the present invention to provide an improved electromagnetic drive device whose stator body is constituted by piling up or laminating in axial alignment a plurality of annular plate elements which can be formed by press-forming of a high productivity.

Briefly, according to the present invention, there is provided an electromagnetic drive device having a stator body composed of a core portion and a yoke portion serially arranged in axial alignment with a non-magnetic portion placed therebetween, a plunger slidably received in an inner bore formed in at least one of the yoke portion and the core portion in the stator body and resiliently urged in one direction, and an electromagnetic coil for exciting the stator body to move the plunger in the axial direction thereof against the resilient force. The stator body is constituted by piling up in axial alignment and bodily joining a plurality of core portion annular plate elements made of a magnetic material to form the core portion, a plurality of yoke portion annular plate elements made of a magnetic material to form the yoke portion, and a plurality of non-magnetic portion annular plate elements made of a non-magnetic material to form the non-magnetic portion.

With this configuration, the plurality of annular plate elements constituting the stator body are obtained by being punched or blanked out by a press from a plate member and therefore are at a low cost. Further, the non-magnetic portion placed between the core portion and the yoke portion each made of a magnetic material can be formed easily and completely only by placing and piling up the plural non-magnetic portion plate elements between the plural core portion plate elements made of a magnetic material and the plural yoke portion plate elements made of a magnetic material, so that the magnetic leakage of magnetic flux from one of the yoke portion and

the core portion to the other can be prevented. Accordingly, since the cost can be reduced in manufacturing the stator body having the core portion and the yoke portion which are serially arranged in axial alignment with the non-magnetic portion placed therebetween, the manufacturing cost for the electromagnetic drive device can be reduced, and it does not occur that the magnetic attraction force exerted on the plunger is weakened due to the leakage of the magnetic flux from one of the yoke portion and the core portion to the other.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

The foregoing and other objects and many of the attendant advantages of the present invention may readily be appreciated as the same becomes better understood by reference to the preferred embodiments of the present invention when considered in connection with the accompanying drawings, wherein like reference numerals designate the same or corresponding parts throughout several views, and in which:

Figure 1 is a longitudinal sectional view showing the general construction of an electromagnetic drive device in the first embodiment according to the present invention;

Figure 2 is a sectional view of a stator body in the first embodiment shown in Figure 1:

Figure 3 is an enlarged, fragmentary perspective view of one of embossed portions formed on each of annular plate elements of the stator body for joining the annular plate elements with one another;

Figure 4 is a sectional view of the embossed portion taken along the line 4-4 in Figure 3;

Figure 5 is a sectional view of the embossed portion taken along the line 5-5 in Figure 4; and

Figure 6 is a sectional view of another stator body in the second embodiment used in place of that shown in Figure 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, an electromagnetic drive device in the first embodiment according to the present invention will be described with reference to Figures 1 to 5. In this particular embodiment, the present invention is applied to a solenoid-operated valve, and an electromagnetic drive device 10 of the solenoid-operated valve in the embodiment is designed to linearly reciprocate a spool (operating member) 24 of a valve section (operating device) 20 which is provided in axial alignment therewith.

As shown primarily in Figures 1 and 2, the electromagnetic drive device 10 is composed of a stator body 11 which is constituted by piling up or laminating and bodily joining a plurality of annular plate elements 15a1 through 15a3, 15b, 15c in axial alignment, a cover 16 made of a magnetic material which covers the stator body 11 thereby to connect the axial opposite ends of the same magnetically with each other, a plunger 17 and an electromagnetic coil 18. The stator body 11 is composed of a core portion 12 and a yoke portion 13 which are serially arranged in axial alignment with a non-magnetic portion 14 provided therebetween. With respect to the outer shape thereof, the stator body 11 extends in a predetermined diameter from the rear end of the yoke portion 13 through the non-magnetic portion 14 up to the portion close to the forward end portion of the core portion 12, and a flange portion 11d is formed at the forward end portion of the core portion 12. Further, in the stator body 11, an inner bore 11a of another predetermined diameter is formed to extend from the rear end of the yoke portion 13 through the non-magnetic portion 14 up to the axial mid position of the core portion 12 in coaxial alignment with the axis of the stator bore 11, and a center hole 11c which is smaller in diameter than the inner bore 11a is formed from the axial mid position up to the forward end of the core portion 12 in axial alignment with the inner bore 11a.

The plunger 17 is made of a magnetic material in its entirety and is guided and supported slidably in the inner bore 11a of the stator body 11. The plunger 17 is movable between an advanced position (shown at the lower half in Figure 1) where its forward end surface 17a at the side of the valve section 20 abuts on an inner end surface of the inner bore 11a through a washer 19, and a retracted position (shown at

the upper half in Figure 1) where its rear end surface 17b abuts on the inner bottom surface of the cover 16. In the inner bore 11a, an electromagnetic section fluid chamber (B) is defined between the forward end surface 17a of the plunger 17 and the inner bore 11a of the stator body 11, while a rear end fluid chamber (A) is defined between the rear end surface 17b of the plunger 17 and the inner bottom surface of the cover 16. The rear end fluid chamber (A) and the electromagnetic section fluid chamber (B) are in communication with each other through a communication hole 17c which is formed in the plunger 17 to pass through axially of the same.

The vale section 20 is composed of a valve sleeve 21 and the aforementioned spool 24 slidably received in a valve hole 22 which is formed coaxially in the valve sleeve 21. The valve sleeve 21 is secured to the stator body 11 in axial alignment therewith by caulking the opening end portion of the cover 16 with its flange portion at the rear end portion being in abutting contact with the flange portion at the forward end portion of the stator body 11. The spool 24 is resiliently urged toward the electromagnetic drive section 10 by means of a spring (not shown), which is interposed between itself and a plug member (not shown) screwed into a forward end portion (not shown) of the valve sleeve 21. A rod portion 24a which is formed to protrude from the rear end of the spool 24 extends passing through the center hole 11c of the stator body 11 and abuts on the forward end surface 17a of the plunger 17. Thus, in the inoperative state, the plunger 17 is kept at the aforementioned retracted position where the rear end surface 17b thereof abuts on the inner bottom surface of the cover 16. An intermediate fluid chamber (C) formed at the mid position between the stator body 11 and the valve sleeve 21 communicates, on one hand, with the electromagnetic section fluid chamber (B) through an annular clearance which is formed between the center hole 11c of the stator body 11 and the rod portion 24a of the spool 24 and, on the other hand, with the external of the solenoid-operated valve through a labyrinth supply/drain passage 23 composed of an annular groove 23a and cutouts 23b, 23c.

As shown in Figures 1 and 2, the stator body 11 is composed of the core portion 12 and the yoke portion 13 which are arranged serially in axial alignment with each

other with the non-magnetic portion 14 placed therebetween. Each of the core portion 12, the yoke portion 13 and the non-magnetic portion 14 is constituted by piling up or laminating in axial alignment and bodily joining a plurality of annular plate elements 15 which are formed by being punched or blanked out from a thin metal plate of the thickness of e.g., 0.5 millimeter.

The non-magnetic portion 14 denoted as a zone (F) in Figure 2 is constituted by piling up a plurality of non-magnetic portion annular plate elements 15c made of a non-magnetic material (e.g., austenite-base stainless steel) one after another. The inner and outer diameters of each non-magnetic portion annular plate element 15c coincide respectively with the diameter of the inner bore 11a and the outer diameter of the portion of the stator body 11 excepting for the flange portion 11d. As shown in Figures 3 to 5, at three positions circumferentially spaced at equiangular intervals on an annular body portion (S) thereof, each non-magnetic portion annular plate element 15c is provided with embossed portions (T) which are formed by half-blanking each to take an arc shape of a predetermined width. The thickness (d) between the front surface (Ta) and the reverse surface (Tb) of each embossed portion (T) in a direction normal to the surface of the body portion (S) is almost the same as the thickness of the body portion (S). The half-blanking for the embossed portions (T) can be performed simultaneously of blanking or punching out the body portion (S). The prominent front surfaces (Ta) of the embossed portions (T) formed on each non-magnetic portion annular plate element 15c are respectively fit in the corresponding hollow reverse surfaces (Tb) of the embossed portion (T) formed on another non-magnetic portion annular plate element 15c which is to be piled thereon, so that all the non-magnetic portion annular plate elements 15c are joined bodily in axial alignment thereby to form the non-magnetic portion 14.

The yoke portion 13 denoted as a zone (E) in Figure 2 is constituted by piling up or laminating a plurality (larger in number than the non-magnetic portion annular plate elements 15c) of yoke portion annular plate elements 15b made of a magnetic material (e.g., cold rolled steel plate desirably of a high fineness) one after another. The shape

and dimension of each yoke portion annular plate element 15b are the same as those of each non-magnetic portion annular plate element 15c. In the same manner as the non-magnetic portion annular plate elements 15c, each yoke portion annular plate element 15b is piled or laminated on another yoke portion annular plate element 15b with the prominent front surfaces (Ta) of the embossed portions (T) on one element (15b) being respectively fit in the hollow reverse surfaces (Tb) of those on another element (15b), so that all the yoke portion annular plate elements 15b are joined bodily in axial alignment thereby to form the yoke portion 13. Further, the prominent front surfaces (Ta) or the hollow reverse surfaces (Tb) of the annular plate element 15b of the yoke portion 13 which element is closest to the side of the non-magnetic portion 14 is fit in the hollow reverse surface (Tb) or the prominent upper surface (Ta) of the annular plate element 15c of the non-magnetic portion 14 which element is closest to the side of the yoke portion 13, so that the yoke portion 13 and the non-magnetic portion 14 are joined bodily in axial alignment.

As shown in Figure 2, the core portion 12 is partitioned into three (i.e., first to third) zones D1, D2 and D3, and each of core portion annular plate elements 15a1, 15a2 and 15a3 in the zones D1, D2 and D3 is made of a magnetic material. Each first core portion annular plate element 15a1 takes the quite same configuration as each yoke portion annular plate element 15b inclusive of the embossed portions (T). Except that the inner diameter is that of the center hole 11c, each second core portion annular plate element 15a2 takes the same configuration as each first core potion annular plate element 15a1 inclusive of the embossed portions (T). Further, except that the outer diameter is that of the flange portion 11d, each third core portion annular plate element 15a3 takes the same configuration as each second core portion annular plate element 15a2 inclusive of the embossed portions (T). In the same manner as the yoke portion annular plate elements 15b and the non-magnetic annular plate elements 15c, the first through third core portion annular plate elements 15a1, 15a2, 15a3 are joined bodily in axial alignment each by being fit in another to be piled thereon at the embossed portions (T) thereof. The embossed portions (T) of the first core portion annular plate

element 15a1 at an end in the zone (D1) and the embossed portions (T) of the non-magnetic portion annular plate element 15c at the facing side of the non-magnetic portion 14 are brought into fitting engagement, so that the core portion 12 and the non-magnetic portion 14 are joined bodily in axial alignment with each other.

As described above, the stator body 11 which is composed of the non-magnetic portion 14 and the core portion 12 and the yoke portion 13 serially arranged in axial alignment at the axial opposite ends of the non-magnetic portion 14 and which has the inner bore 11a and the center hole 11c is formed by piling up and bodily joining the plural annular plate elements 15c, 15b and 15a1 to 15a3 in axial alignment with one another. In this particular embodiment, in order to make the sliding movement of the plunger 17 smooth and to make the clearance relative to the plunger 17 minimum for stronger magnetic attraction force, the inner bore 11a and the outer surface of the stator body 11 formed in this way are finished and improved in precision. Either one or both of the internal surface of the inner bore 11a of the stator 11 and the outer or external surface of the plunger 17 are coated with a thin non-magnetic film (e.g., plating of a nickel-phosphorus film in the depth of 20 to 50 micrometers, painting or coating of a resin of Teflon® or the like), whereby it can be obviated that two magnetic bodies are directly contacted with each other thereby to impede the smooth relative sliding movement therebetween.

When electric current is applied to the electromagnetic coil 18 of the electromagnetic drive device 10, the stator body 11 is excited in proportion to the magnitude of the electric current applied thereto thereby to make the plunger 17 attracted toward the core portion 12, and thus, the spool 24 of the operating device 20 is moved against the resilient force of the spring (not shown), as depicted at the lower half in Figure 1. With movement of the plunger 17, the rear end fluid chamber (A) varies in volume, and the oil around the solenoid-operated valve within an oil pan (not shown) containing the same is charged into the rear end fluid chamber (A) or discharged therefrom through the labyrinth supply/drain passage 23, the intermediate fluid chamber (C), the clearance between the center hole 11c and the rod portion 24a, the

electromagnetic section fluid chamber (B), and the communication nole 17c.

In the foregoing embodiment, the non-magnetic portion 14 between the core portion 12 and the yoke portion 13 each made of a magnetic material can be formed easily and completely by piling up or laminating the plural non-magnetic portion annular plate elements 15c made of a non-magnetic material between the plural core portion annular plate elements 15a1, 15a2 and 15a3 made of a magnetic material and the plural yoke portion annular plate elements 15b made of a magnetic material. Thus, the magnetic flux can be prevented from leaking from the yoke portion 13 directly to the core portion 12 without passing through the plunger 17, and it is ensured that the magnetic flux passes from the yoke portion 13 reliably through the plunger 17 to the core portion 12, as indicated by a loop line with arrow in Figure 1. Therefore, it does not occur that such magnetic leakage causes the magnetic attraction force on the plunger 17 to be weakened. Further, the plural annular plate elements 15 (15a1, 15a2, 15a3, 15b, 15c) which constitute the stator body 11 of the electromagnetic drive device 10 can be obtained by being blanked out from a plate member on a press, so that the electromagnetic drive device 10 can be reduced in the manufacturing cost.

Also in the foregoing embodiment, the plural embossed portions (T) each of which is prominent at the side of the front surface (Ta) and hollow at the side of the reverse surface (Tb) are formed on the body portion (S) of each annular plate member 15, and the prominent front surface (Ta) of the embossed portion (T) on each annular plate element 15 is fit in the hollow reverse surface (Tb) of the embossed portion (T) on another annular plate element 15 to be piled thereon, and in this way, all the annular plate elements 15 are joined one after another. Thus, it becomes quite easer to join all the annular plate elements 15 bodily in axial alignment with one another. In addition, since the embossed portions (T) can be formed at the same time when each annular plate element 15 is formed by being blanked out on a press, the forming of the embossed portions (T) can be practiced without incurring a substantial extra cost, so that the manufacturing cost for the annular plate elements 15 does not increase.

Although in the foregoing embodiment, each embossed portion (T) is

predetermined in width and arc in cross-section, it is not limited to the shape. Rather, each embossed portion (T) may take the cross-section of a shallow trapezoid or any arbitrary shape. Or, the embossed portion (T) may be formed by practicing half-blanking process at each designated positions on the body portion (S) of each annular plate member 15 with a round punch and a die with a die hole of the same diameter, and all the annular plate elements 15 may be joined by fitting the prominent front surfaces (Ta) of the embossed portions (T) of each annular plate element 15 in the corresponding hollow reverse surfaces (Tb) of the embossed portions (T) of another plate element 15 to be piled thereon.

Also in the aforementioned embodiment, the inner bore 11a of the stator body 11 constituted by joining the plural annular plate members 15 is finished thereby to smoothen the sliding movement of the plunger 17 in the inner bore 11a, and the clearance between the plunger 17 and the inner bore 11a is minimized to increase the magnetic attraction force, so that the performance of the electromagnetic drive device 10 can be enhanced. In this particular embodiment, since the half-blanking for the embossed portions (T) is carried out simultaneously of the punching-out of the body portion (S), high precision can be attained as to the relative position between the inner bore 11a and each of the embossed portions (T), and the internal surface of each annular plate element 15 which can be obtained by a punching-out operation on a press is kept at a certain degree of preciseness as a matter of course. Accordingly, the punched-out internal surfaces of the plural annular plate elements 15 which are joined at the embossed portions (T) thereof each fit in another have a high concentricity, and thus, a small allowance is sufficient for finishing the inner bore 11a, so that the machining cost for such finish process can be restrained from increasing.

Further, in the foregoing embodiment, the stator body 11 is provided with the flange portion 11d only at the forward end portion serving as the core portion 12. However, in the second embodiment, as shown in Figure 6, there may be used another stator body 11A which is provided with another flange portion 11e also at the rear end portion serving as the yoke portion 13 in addition to the flange portion 11d provided at

the forward end portion. Therefore, in the second embodiment, the yoke portion 13 is composed of two zones E1 and E2, and first yoke portion annular plate elements 15b1 in the zone E1 take the same configuration as the yoke portion annular plate elements 15b shown in Figure 2, while second yoke portion annular plate elements 15b2 in the zone E2 take the same configuration as the third core portion annular plate elements 15a3 shown in Figure 2 except for the difference in the diameter of the internal surface. Further, joining all the annular plate elements 15 at the embossed portions (T) thereof can be done in the same manner as those shown in Figurers 3 through 5. Since the laminated stator body 11A can be easily separated into two or more laminated blocks at any desired potions within any of the zones D1, D2, E1 and E2 by disengaging the embossed portions (T), any difficulty does not arise in assembling the electromagnetic coil 18.

Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the present invention may be practiced otherwise than as specifically described herein.